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INTERMEDIATE BUS POWER ARCHITECTURE

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INTERMEDIATE BUS POWER ARCHITECTURE

BACKGROUND

[0001] Intermediate bus (IB) power architectures are one solution for applications that require low cost and flexibility in power system design. As illustrated in **Figure 1**, a prior art power system design is shown that distributes an input voltage of +48V to a number of desired system voltages such as +3.3V, +1.5V, and +5V. The design uses an intermediate bus power architecture configured with a common intermediate bus **100** that supplies power from a first set of power converters (e.g., isolated converters **105**) to a second set of power converters (e.g., non-isolated converters **110**). The non-isolated converters **110** operate from the common voltage on the intermediate bus **100**. However, extending this architecture to an N+1 application required additional components to isolate the non-isolated converters **110** from power component failures that can disturb the common intermediate bus voltage.

[0002] For example, an input fault within one of the non-isolated converters **110** will cause a disturbance on the intermediate bus **100** and thereby affect the operation of the remaining good non-isolated converters **110**. This situation was addressed by adding fault protection components to the circuit. For example, the intermediate bus **100** includes a fuse **115**, an isolation diode **120**, and local storage capacitance **125** on the input of each non-isolated converter **110**. Upon an input fault on a failing non-isolated converter **110**, the fuse **115** would be cleared to remove the failing non-isolated converter from the circuit. The isolation diode **120** and local storage capacitance **125** provide isolated stored energy to the remaining good non-isolated converters that allow them to operate through the disturbance created on the intermediate bus **100** as the fuse is cleared. Additionally, isolation diodes **130** are positioned on the outputs of all the isolated power converters **105** to prevent faults within these converters from affecting the intermediate bus **100**. The use of isolation diodes **120** and **130** can increase power system losses and can decrease power system efficiency. In general, additional circuit components can add cost, increase power losses, and can reduce hardware reliability.

[0003] The circuit may also include any number of other components such as a hot swap manager **135** and a filter **140**. The hot swap manager **135** is a component that provides control of in-rush current that may occur when plugging in components. The filter **140** may be an EMI-type filter to reduce or prevent high frequency noise from traveling back through the circuit. These components are not important to the discussions herein and will not be further described.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate various example systems, methods, and so on that illustrate various example embodiments of aspects of the invention. It will be appreciated that the illustrated element boundaries (e.g., boxes, groups of boxes, or other shapes) in the figures represent one example of the boundaries. One of ordinary skill in the art will appreciate that one element may be designed as multiple elements or that multiple elements may be designed as one element. An element shown as an internal component of another element may be implemented as an external component and vice versa. Furthermore, elements may not be drawn to scale.

[0005] Figure 1 illustrates a prior art example of power system design and an intermediate bus architecture.

[0006] Figure 2 illustrates one example of a power conversion system including an intermediate bus architecture.

[0007] Figure 3 illustrates another example circuit configuration of an intermediate bus architecture included in an example power conversion system.

[0008] Figure 4 illustrates another example of an intermediate bus architecture.

[0009] Figure 5 illustrates an example methodology of converting an input power level.

[0010] Figure 6 illustrates an example methodology associated with forming a power conversion circuit.

DETAILED DESCRIPTION

[0011] The following includes definitions of selected terms employed herein. The definitions include various examples and/or forms of components that fall within the scope of a term and that may be used for implementation. The examples are not intended to be limiting. Both singular and plural forms of terms may be within the definitions.

[0012] "Logic", as used herein, includes but is not limited to hardware, firmware, software and/or combinations of each to perform a function(s) or an action(s), and/or to cause a function or action from another component. For example, based on a desired application or needs, logic may include a software controlled microprocessor, discrete logic like an application specific integrated circuit (ASIC), a programmed logic device, a memory device containing instructions, or the like. Logic may include one or more gates, combinations of gates, or other circuit components. Logic may also be fully embodied as software. Where multiple logical logics are described, it may be possible to incorporate the multiple logical logics into one physical logic. Similarly, where a single logical logic is described, it may be possible to distribute that single logical logic between multiple physical logics.

[0013] An "operable connection", or a connection by which entities are "operably connected", is one in which signals, physical communication flow, and/or logical communication flow may be sent and/or received. Typically, an operable connection may include a physical interface, an electrical interface, and/or a data interface, but it is to be noted that an operable connection may include differing combinations of these or other types of connections sufficient to allow operable control. For example, two entities can be operably connected by being able to communicate signals to each other directly or through one or more intermediate entities like a processor, operating system, other software, a logic device, a chip, a circuit, or other entity. Logical and/or physical communication channels can be used to create an operable connection.

[0014] "Signal", as used herein, includes but is not limited to one or more electrical or optical signals, analog or digital, one or more computer or processor instructions, messages, a bit or bit stream, or other means that can be received, transmitted, and/or detected.

[0015] It has proven convenient at times, principally for reasons of common usage, to refer to signals as voltages, currents, power levels, bits, values, elements, symbols, characters, terms, numbers, or the like. It should be borne in mind, however, that these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise, it is appreciated that throughout the description, terms like processing, providing, transmitting, supplying, computing, calculating, determining, displaying, or the like, refer to actions and processes of a computer system, logic, processor, or similar electronic device that manipulates and/or transforms signals represented as physical (electronic) quantities.

[0016] Illustrated in **Figure 2** is one example of a power conversion circuit **200** configured to convert an input power level **205**, such as a voltage level from a power source, to one or more desired output power levels **210**. One application of the power conversion circuit **200** can be to take a +48 volt input power level **205** and convert or distribute the power level to multiple different output power levels **210**. The output power levels **210** can include multiple voltage levels that can be used as input to electronic components requiring system loads less than the input power level **205**. Examples of electronic components can include application specific integrated circuits (ASIC), other types of chips, circuits, or other logic devices.

[0017] It will be appreciated that the power conversion circuit **200** can be used in many electronic environments such as on a printed circuit board of a computer or other electronic device where power levels are converted/distributed to other components. An electronic device may also include any number of power conversion circuits **200** that may have different combinations and configurations of components based on the desired types of power conversion and power distribution needed.

[0018] With further reference to **Figure 2**, the power conversion circuit **200** can include a first set of power converters **215** and a second set of power converters **220** that are connected by an interleaved intermediate bus **225**. The first set of power converters **215** are configured to convert the input power level **205** to a desired intermediate level. For example, the power converters **215** can be +48 volt to +12 volt converters. Of course, other types of converters can be used that have different

input/output ranges as well as other combinations of converters. The output from the power converters **215** are supplied to the input of the second set of power converters **220** through operable connections with the interleaved intermediate bus **225**. The second set of power converters **220** further convert the power level to a desired output level **210**.

[0019] As one example, the interleaved intermediate bus **225** can be configured with multiple independent intermediate buses to supply input to individual power converters **220**. If a fault occurs on any one of the independent intermediate buses, the fault may affect the particular power converter **220** that it is connected to but would not affect the other, separate independent buses and thus, not affect the other power converters **220**. Furthermore, to support an N+1 application, the conversion circuit **200** can be configured to have multiple power converters **220** operating in parallel to support a particular system load and provide N+1 redundancy.

[0020] For example, a group of the power converters **220** can have their outputs combined to generate one system output level **210** where the group includes at least one redundant power converter. Thus, if one of the power converters **220** in the group would go down, the group would still have enough power to generate the system output level **210** associated with the group. Thus generally speaking, each output **210** of the circuit has connected to it, an extra power converter **220** and an extra independent intermediate bus from one of the power converters **215** so that any of the independent intermediate buses associated with a group power converters **220** can fail and the output **210** can still be generated.

[0021] As will be described with reference to the following examples, the interleaved intermediate bus **225** can be configured to provide voltages on multiple intermediate buses from the first set of power converters **215** to the second set of power converters **220** such that a loss or disturbance on any one of the multiple intermediate buses will not affect the system load on the other intermediate buses. Furthermore, the interleaved intermediate bus **225** can be configured to supply redundant input to the second set of power converters **220** from one or more output power levels from the first set of power converters **215**. With the interleaved

intermediate bus **225**, the bus can be configured without fault protection components and still provide a desired level of system reliability.

[0022] It will be appreciated that the first set of power converters **215** can include isolated power converters. The second set of power converters **220** can include non-isolated converters. Of course, other types of power converters or transformers can be used and can be interchanged and/or combined in different combinations and configurations.

[0023] Illustrated in **Figure 3** is another example of a power conversion system **300** that includes an example of an intermediate power bus architecture **305**. In the illustrated example, the power conversion circuit **300** is configured to convert a +48 volt input voltage level **310** into three output voltages (e.g. system loads) shown as +3.3 volts, +1.5 volts, and +5 volts. It will be appreciated that other input levels can be used as well as other types and combinations of converters to generate one or more desired output levels. It will be further appreciated that each output voltage can be generated by using one or more power converters, such as non-isolated converters **315**, that are selectively combined in parallel.

[0024] For example, the +3.3 volt output level can be generated by combining five (5) non-isolated converters **315**. Additionally, each output voltage (e.g. +3.3 volts, +1.5 volts, and +5 volts) can be produced by having a redundant (N+1) non-isolated converter within its group. Thus, if one of the non-isolated converters **315** in the group associated with the +3.3V output would fail, the other four (4) non-isolated converters would generated enough power to provided the +3.3V output.

[0025] The circuit **300** can include one or more power converters, such as isolated intermediate bus converters **320**, that can be configured to distribute the input voltage level of +48 volts to an intermediate voltage level. The intermediate voltage level is then supplied to the non-isolated converters **315** across the intermediate bus architecture **305**. In one example, each isolated converter **320** can be a power transformer that converts a +48 volt input level to a +12 volt output level. One example is a BusQor BQ50120QTA20 bus converter module manufactured by

SynQor. Of course, other types and numbers of converters can be used, as well as converters having different input/output ranges.

[0026] The non-isolated converters **315** can be, for example, a DC/DC converter such as a SIL30C series non-isolated converter manufactured by Artesyn Technologies. Each of the non-isolated converters **315** can be configured to accept a range of input voltages and provide a range of output voltages. For example, the non-isolated converter **315** can include one or more trim pins that allow the output to be adjustable to a selected voltage level, for example between a 0.9 volt to 5 volt output voltage range. In this manner, a selected number of non-isolated converters **315** can be combined in parallel to produce a desired output voltage level. For example, the +5 volt output level shown in **Figure 3** can be produced by using three (3) non-isolated converters **315**.

[0027] With further reference to **Figure 3**, the intermediate bus architecture **305** can be configured to be interleaved to supply independent and redundant input to the set of non-isolated converters **315** from the output power levels from the set of isolated converters **320**. For example, the bus architecture **305** can include multiple intermediate buses (e.g. buses A-E) where each bus carries an output signal that is separate and independent from the other bus signals, making each bus A-E isolated from each other. Each intermediate bus A-E is configured to provide input power to no more than one non-isolated converter **315** per output voltage (e.g., 3.3 volts, 1.5 volts, 5 volts). In other words, any given intermediate bus **A-E** supplies only one input per group of non-isolated converters.

[0028] Thus in the example configuration, the +3.3 volt output is generated from a first group of five (5) non-isolated converters **315** operating in parallel to support the load and provide N+1 redundancy. As such, five intermediate buses **A-E** are configured to provide an independent input voltage to each of the five non-isolated converters **315**. The other non-isolated converters are combined as two other groups that generate the other system voltages (e.g., +1.5 volts and +5 volts). Each group of non-isolated converters are configured to receive selective input from the five intermediate buses **A-E** in a distributed manner.

[0029] In a particular example from **Figure 3**, the intermediate bus "A" is configured to provide input power (e.g. voltage) to one non-isolated converter **315** associated with the output voltage +3.3 volts and does not provide input to any other non-isolated converter associated with the same output voltage. This can be regarded as a one-to-one relationship where within a group of non-isolated converters **315**, no two converters share an intermediate bus or receive input from a common intermediate bus. Rather, the intermediate bus "A" can be distributed to a different non-isolated converter in another group, such as a converter associated with the +1.5 volt output. Likewise, the non-isolated converters **315** that are grouped and associated with a particular output voltage are configured to receive input power from different intermediate buses **A-E** from the isolated converters **320** such that a selected number of the isolated converters **320** provide an independent input voltage to one non-isolated converter **315** per output voltage. Thus, for each group of non-isolated converters **315** per output voltage, the group includes a redundant bus from the independent intermediate buses **A-E**.

[0030] The interleaved intermediate bus **305** can be configured, in one example, where each independent bus **A-E** is split to provide an input to two (2) non-isolated converters **315**. It will be appreciated that the intermediate bus **305** can be configured where the independent buses **A-E** are configured to provide input to one or more non-isolated converters **315**. Another example of an interleaved bus configuration is shown in **Figure 4**.

[0031] Illustrated in **Figure 4** is another example of a power conversion system **400** that includes an interleaved intermediate bus **405**. Similar to the previous examples, the intermediate bus **405** has an architecture configured to connect one set of power converters **410** to a second set of power converters **415**. Overall, the power conversion system **400** is configured to convert an input voltage **420** into one or more output voltages such as output 1, output 2, and output 3. Output from each of the power converters **410** are provided on an independent intermediate bus labeled **A**, **B**, and **C**, respectively. The output from each independent bus **A-C** can then be supplied as an independent input to separate power converters **415** that are combined to form the output 1. In other words, any one of the independent buses A, B, or C is not connected to more than one power converter **415** in the group that forms output 1.

[0032] The interleaved intermediate bus **405** is interleaved by configuring the independent buses **A-C** to provide separate input to a group of power converters **415** per output voltage (e.g. output 1). The independent buses **A-C** are also split to provide selective input to other groups of power converters **415** (e.g. output 2 and/or 3). For example, the bus "A" provides input to two other power converters, one forming the group associated with output 2 and one converter associated with the group forming output 3. The independent buses B and C are also similarly interleaved to provide input power/voltage to one or more power converters **415**.

[0033] As described previously, each of the outputs 1-3 are formed with a redundant power converter **415** (e.g. N+1) that receives power from an independent bus **A-C**, thus making that bus a redundant bus. This configuration allows one power converter **415** per output group to fail or one of the independent buses **A-C** to fail without affecting the outputs 1, 2, or 3.

[0034] In this manner, fault protection components may be eliminated from the interleaved intermediate bus architecture **405** since a power component failure will only affect one power path (e.g., voltage on bus A, B, or C) associated with a particular group of power converters **415** that are combined to form a desired output. The remaining power paths will be undisturbed and can support the system load due to the N+1 redundancy in the number of power converters **415**. It will be appreciated that in the design of the power conversion system **400** or other circuits described herein, any number of power converters can be used and combined in any desired manner to convert an input voltage level to a desired output voltage level.

[0035] With reference to **Figure 5**, an example methodology **500** associated with converting a power level to one or more output power levels is shown. While for purposes of simplicity of explanation, the illustrated methodologies are shown and described as a series of blocks, it is to be appreciated that the methodologies are not limited by the order of the blocks, as some blocks can occur in different orders and/or concurrently with other blocks from that shown and described. Moreover, less than all the illustrated blocks may be required to implement an example methodology.

Furthermore, additional and/or alternative methodologies can employ additional, not illustrated blocks.

[0036] In the flow diagrams, blocks denote "processing blocks" that may be implemented with logic. A flow diagram does not depict syntax for any particular programming language, logic device, methodology, or style (e.g., procedural, object-oriented). Rather, a flow diagram illustrates functional information one skilled in the art may employ to develop logic to perform the illustrated processing. It will be further appreciated that electronic and software applications may involve dynamic and flexible processes so that the illustrated blocks can be performed in other sequences that are different from those shown and/or that blocks may be combined or separated into multiple components.

[0037] With reference to **Figure 5**, initially, an input power is provided **(Block 505)** such as a voltage level. The input power is then converted to multiple intermediate power levels that are carried on independent buses **(Block 510)**. In one example, the intermediate power levels can include multiple outputs of any equal value or in another example, can include different output values. The multiple intermediate power levels are then inputted as independent signals to a first set of power converters **(Block 515)**. In this respect, the first set of power converters could include a group of non-isolated converters that are combined together to form a single output voltage. As an example, the first set of power converters could correspond to the five (5) non-isolated converters **315** grouped and associated to the +3.3V output shown in **Figure 3**. An independent input signal is inputted to each non-isolated converter **315** in that group which includes a redundant input signal for the redundant non-isolated converter in that group.

[0038] The multiple intermediate power levels are also interleaved to provide independent input signals to a second set of power converters including a redundant input signal **(Block 520)**. In this respect, the second set of power converters could include another group of non-isolated converters that are combined to form a separate output voltage such as the +1.5 volt output shown in **Figure 3**. Thus, the multiple intermediate power levels are supplied as input power to no more than one converter per output voltage. Additionally, each set or group of power converters includes a

redundant converter that receives input from an independent bus that is redundant for that group.

[0039] Illustrated in **Figure 6** is an example methodology **600** associated with forming a power conversion circuit. The methodology **600** may be applied, for example, when fabricating or manufacturing a circuit, a printed circuit board, a chip, and/or other logic device and may be applied to form any of the example interleaved intermediate buses or similar bus architectures described above.

[0040] With reference to **Figure 6**, a plurality of power converters can be positioned to convert an input voltage to a plurality of intermediate voltages (block **605**). This may include positioning the power converters like the set of isolated converters shown in Figure 3. At least a first group of power converters are grouped to generate a first output voltage including at least one redundant converter (block **610**) and grouping a second group of power converters to generate a second output voltage including at least one redundant power converter (block **615**). Outputs of the plurality of power converters are operably connected to inputs of the first group of power converters as independent intermediate buses (block **620**). Selected buses of the independent intermediate buses are operably connecting to separate inputs of the second group of power converters (block **625**).

[0041] As described in previous examples, using independent buses allow the buses to be designed without including fault protection components. The operably connecting steps form an interleaved power bus that includes the independent intermediate buses. For example, in each group of power converters, the inputs can be connected to each of the independent intermediate buses as a one-to-one relationship. In other words, only one input from each intermediate bus is connected to a group of power converters per each output voltage. Reference to Figures 3 and 4 also give examples of these types of connections, interleaved bus architectures, and relationships of components that can be produced with the methodology **600** or similar methodology.

[0042] It will be appreciated that the power conversion systems and/or circuits as described herein may be embodied in a variety of desired applications. For example,

the power conversion system can be embedded into a computer, a server, a central processing unit (CPU) board, an input/output chassis, and/or in any desired electronic component or product, like an image forming device, where an input power level is desired to be converted to one or more output levels. The input power level can be converted or distributed to different output power levels that become input to components such as ASICS, chips, and/or other logic devices. It will be appreciated that any of the described power converters can be implemented by using isolated converters, non-isolated converters, AC or DC power transformers, other types of converter circuits or logic, and can be interchanged with other types of converters as desired for converting an input power level to a different power level. Furthermore, any of the described bus architectures can be used for redundantly connecting a first set of power converters to a second set of power converters and to supply an intermediate power level as interleaved independent input signals to the second set of power converters.

[0043] Using the described power conversion systems, circuits, bus architectures, and methodologies, an intermediate bus architecture in an N+1 application can be implemented without fault protection components such as fuses, isolation diodes, and/or capacitors. In one example, fuses can be eliminated and overload protection can be provided by using the current limit latching function of each intermediate bus power converter. Power losses may be reduced due to the elimination of multiple isolation diodes in series. Efficiency can be increased due to the reduced power losses. Additionally, by eliminating components, a printed circuit board area can be reduced with the described or similar architecture. Furthermore, eliminating components in the intermediate bus architecture may increase reliability and may increase efficiency and lower the cost associated with the components.

[0044] While example systems, methods, and so on have been illustrated by describing examples, and while the examples have been described in considerable detail, it is not the intention of the applicants to restrict or in any way limit the scope of the appended claims to such detail. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the systems, methods, and so on described herein. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention,

in its broader aspects, is not limited to the specific details, the representative apparatus, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of the applicants' general inventive concept. Thus, this application is intended to embrace alterations, modifications, and variations that fall within the scope of the appended claims. Furthermore, the preceding description is not meant to limit the scope of the invention. Rather, the scope of the invention is to be determined by the appended claims and their equivalents.

[0045] To the extent that the term "includes" or "including" is employed in the detailed description or the claims, it is intended to be inclusive in a manner similar to the term "comprising" as that term is interpreted when employed as a transitional word in a claim. Furthermore, to the extent that the term "or" is employed in the claims (e.g., A or B) it is intended to mean "A or B or both". When the applicants intend to indicate "only A or B but not both" then the term "only A or B but not both" will be employed. Thus, use of the term "or" herein is the inclusive, and not the exclusive use. See, Bryan A. Garner, A Dictionary of Modern Legal Usage 624 (2d. Ed. 1995).